

average roughness R_a of the film is about 0.45 nm when the substrate is maintained at 550 °C and processed under a pressure of 0.3 Torr.

On the other hand, the average roughness R_a of a gate insulating film for MISFET is required to be smaller than or equal to 0.2 nm when the gate length thereof is 0.1 μm or less.

Summary of the Invention

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Accordingly, the present invention strives to provide a new and useful film forming method capable of solving all of the aforementioned problems.

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Specifically, it is an objective of the present invention to provide a film forming method capable of reducing a surface roughness of a dielectric film when forming the dielectric film through a MOCVD method.

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It is another objective of the present invention to provide a method for forming a dielectric film by using a metal organic CVD method comprising, the steps of: supplying a metal organic compound into a processing vessel having therein a substrate to be processed; and forming a dielectric film on the substrate, wherein the dielectric film forming step includes: a first step of depositing, in the processing vessel, the dielectric film under a first condition so as to allow a residence time of the metal

organic compound to extend to a first value; and a second step for further depositing the dielectric film under a second condition so as to allow the residence time of the metal organic compound to extend to a second value smaller
5 than the first value.

When the high-k dielectric film such as a HfO_2 film or a ZrO_2 film is formed through the MOCVD in accordance with the present invention, the surface roughness of the film can be controlled. At the same time, deposition of decomposed
10 and/or partially decomposed materials of the metal organic compound on a showerhead or the like can be suppressed.

Brief Description of the Drawings

15 The above and other objects and features of the present invention will become apparent from the following description of preferred embodiments given in conjunction with the accompanying drawings, in which:

20 Fig. 1 shows the structure of a MOCVD apparatus used in accordance with a first preferred embodiment of the present invention;

Fig. 2 illustrates a relationship between the film thickness and the substrate temperature of a HfO_2 film, the processing pressure being a parameter;

25 Fig. 3 describes a relationship between the film thickness and the processing pressure of a HfO_2 film, the

while setting that in step 2 to be large, which can be garnered from the equation given above. The residence time can also be controlled by setting the flow rate of a carrier gas or oxygen gas at a small value in the process of step 1 5 and then increasing the flow rate thereof in the process of step 2.

[Second preferred embodiment]

Figs. 11A to 11E provide a manufacturing process of a 10 semiconductor device in accordance with a second preferred embodiment of the present invention.

Referring to Fig. 11A, a base oxide film 42 composed of a SiO₂ film or a SiON film having a film thickness of 1 nm or less is formed on a silicon substrate 41 by performing 15 a radical oxidization treatment using, e.g., a UV excited oxygen radical, or by performing a plasma radical nitration after the radical oxidization treatment. Then, in the process of Fig. 11B, a metal oxide film 13 such as HfO₂ or ZrO₂ is formed in the two step process as previously 20 described in Fig. 8 on the base oxide film 42 through a metal organic chemical vapor deposition (MOCVD) method with a metal organic material such as tetra(tert-butoxy)hafnium or tetra(tert-butoxy)zirconium at a substrate temperature of 450 - 600 °C.

25 Thereafter, in the process of Fig. 11C, a polysilicon film 44 is deposited on the metal oxide film 43. Although

What is claimed is:

1. A method for forming a dielectric film by using a metal organic CVD method, comprising the steps of:

5 supplying a metal organic compound into a processing vessel having therein a substrate to be processed; and

forming a dielectric film on the substrate,

wherein the dielectric film forming step includes:

10 a first step of depositing, in the processing vessel, the dielectric film under a first condition so as to allow a residence time of the metal organic compound to extend to a first value; and

15 a second step for further depositing the dielectric film under a second condition so as to allow the residence time of the metal organic compound to extend to a second value smaller than the first value.

2. The method for forming a dielectric film of claim 1, wherein, in the first step, the processing pressure in the processing vessel is set at a first processing pressure, and, in the second step, the processing pressure in the processing vessel is set at a second processing pressure which is lower than the first processing pressure.

25 3. The method for forming a dielectric film of claim 1, wherein, in the first step, the flow rate of a carrier gas

or oxygen gas supplied into the processing vessel is set at a first flow rate, and, in the second step, the flow rate of the carrier gas or the oxygen gas is set at a second flow rate which is greater than the first flow rate.

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4. The method for forming a dielectric film of claim 1, wherein the dielectric film is a crystalline film, and in the first step, crystalline nuclei of the dielectric film are formed on the substrate.

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5. The method for forming a dielectric film of claim 1, wherein the metal organic compound is an organic compound containing Hf or Zr, and the dielectric film is a HfO_2 film or a ZrO_2 film.

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6. The method for forming a dielectric film of claim 1, wherein the metal organic compound is tetra(tert-butoxy)hafnium, and the residence time is set to exceed 0.25 second in the first step and to be less than 0.25 second in
20 the second step.

7. The method for forming a dielectric film of claim 6, wherein, in the first step, the processing pressure in the processing vessel is set to exceed 133 Pa, and in the second
25 step, the processing pressure in the processing vessel is set at 133 Pa or below.

8. The method for forming a dielectric film of claim 6, wherein, in the first step, the processing pressure in the processing vessel is set at 200 - 400 Pa, and in the second step, the processing pressure in the processing vessel is
5 set at about 40 Pa or below.

9. The method for forming a dielectric film of claim 6, wherein the first and the second steps of the dielectric film forming step are performed at a temperature of 450 °C
10 or higher.

10. The method for forming a dielectric film of claim 6, wherein the first and the second steps of the dielectric film forming step are performed at a temperature of about
15 550 °C.